ONSET VS. CODA ASYMMETRY IN THE ARTICULATION OF ENGLISH /r/

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ABSTRACT

We describe an asymmetric categorical pattern of onset-coda allophony for English /r/, the post-alveolar rhotic approximant, drawing on published and unpublished information on over 100 child, teenage and adult speakers from prior studies. Around two thirds of the speakers exhibited allophonic variation that was subtle: onset and coda /r/ were typically both bunched (BB), or both tip-raised (RR), with minor within speaker differences. The other third had a more radical categorical allophonic pattern, using both R and B types. Such variable speakers had R onsets and B codas (RB): but the opposite pattern of allophony (BR) was extremely rare. This raises questions as to whether the asymmetry is accidental or motivated by models of syllable structure phonetic implementation.

Keywords: rhotics, ultrasound, allophones, phonology, retroflexion.

1. INTRODUCTION

Subtle allophony is often conditioned by phonetic context, but even if an allophonic pattern is not subtle, it may still invite phonetic explanation. Theories of onset-coda allophony tend to explain subtle differences with reference to general prosodic domain-initial strengthening [12] or onset/coda co-ordination differences [3], [4] that affect inter-gestural timing or gestural strength. Such gestural reorganisation or strengthening has been observed in many allophonic cases (e.g. [7], [24], [19]). Less commonly considered instrumentally are categorical allophone systems, where allophones differ greatly and may appear to be phonetically arbitrary from a synchronic perspective. Some such systems appear to be described adequately with transcription; others may also require instrumental analysis from acoustic and/or articulatory perspectives to begin to tease apart their subtle and less subtle aspects [23].

The English liquid phonemes /r/ and /l/ (we use phonetically abstract labels) have been well studied from both perspectives, but articulatory studies have tended to be limited in the number of participants, for logistical reasons. In this paper we aim to exploit existing ultrasound tongue image (UTI) corpora in a meta-analytic comparison. Quantitative analysis is based on qualitative allocation of tongue shape into two categories, based on data from Scottish speakers and published results from Scottish and American speakers. We reveal the broad onset-coda allophony system in (two rhotic varieties of) English /r/.

Studies of English /r/ such as [4], [6], [13], [17], [27] have shown dialectal, allophonic, coarticulatory and idiosyncratic variation in the tongue shapes underlying approximant /r/, but primarily in the post-vocalic or coda context. In American English, this articulatory variation appears to have little or no acoustic consequence [10], 0, at least in highly constrained lab speech [18]. Yet within a single context, inter-speaker articulatory variation in /r/ may be considerable. The shape that the tongue adopts as active articulator (usually simplified, i.e. captured at a single timepoint, viewed in the mid-sagittal plane, focusing on the surface and the anterior parts in particular) has been classified into a number of shapes [6]. It seems at one extreme that some speakers produce /r/ with the tongue tip raised, retroflexed and retracted, while, at the other end of a continuum (or sequence), other speakers lower the tongue tip behind the lower teeth, somewhat retracted, while bunching up the tongue front to form a very different looking constriction in the same approximate region (postalveolar). In addition, there are secondary labial and tongue dorsum constrictions. (They appear to be taking on a primary role in non-rhotic Southern Standard British English [21]). We focus here just on the lingual articulation.

In Scottish English, which is basically rhotic phonologically, there is strongly systematic social variation in tongue shape for /r/. A series of studies [13], [14], [15], [25], [26] have shown that the tongue shape of Scottish coda /r/ varies on an interspeaker basis (like that of American English), but the Scottish variation is strongly predicted by social class. These studies have found that coda /r/ in young working-class speakers (wordlist data) is predominately tip-up, both around Edinburgh, in the east of central Scotland [13], and Glasgow, in the west [15]. In addition, these more working-class speakers tend to have weaker acoustic correlates of rhoticity in the coda [25], [11], [20] with the possibility that the acoustic nature of /r/ owes more to its "secondary" pharyngeal constriction than its "primary" post-alveolar one. Such derhoticisation among more vernacular speakers is associated with a

tip-up articulation which is delayed temporally [16], while the middle class /r/ differs not just in basic shape (bunched), but dynamically: the bunched target is achieved phonetically earlier in the word [16] and so is associated with a strong rhotic quality for consonantal coda /r/ [14]. The middle-class bunched rhotic even seems to be turning into a rhotic vowel (or syllabic /r/), while helping to cause mergers in the erstwhile pre-rhotic vowel set [14].

With access to the data of the two sociophonetic corpora underlying the work just cited, ECB08 [13], [14] and WCB12 [15], [16], along with access to data from the ULTRAX project [5], we will examine the relationship of coda /r/, well-described in terms of social stratification in the previous literature, to onset /r/, which has received scant attention. We aim to reveal the relevant syllable-based allophonic systems, so far as is possible.

2. METHOD

2.1. Datasets overview

We have accessed raw data from four audio-ultrasound datasets from two research groups, and have undertaken an exhaustive descriptive analysis of the shape of each speaker's /r/ shape based on the methods of [13]. The number of onset and coda /r/ available varied markedly between datasets.

The first group investigated coda /r/ in two socially-stratified pools of young Scottish-accented teenagers aged 12-14. The datasets (ECB08 and WCB12) also included words with onset /r/, which are examined here systematically for the first time (see [14] footnote 1).

The second group examined the abilities of typically developing Scottish-resident children aged 6-12 to produce non-English speech sounds in a number of experimental conditions. The children incidentally produced a number of words containing /r/, mainly in codas, none of which has been analysed previously.

We also reanalyse published work on American English /r/. This gives us information on 110 speakers' approximant /r/ systems.

2.1. Classification of /r/ into categories

The basic classification of /r/ shape we adopt was used in the first group [13]. It was based on agreed "visual transcription" of tongue shape into one of four categories, paraphrased here:

- TIP UP – the overall shape of the tongue surface is either straight and steep, or has a concave shape, suggesting retroflexion.
- FRONT UP – the tongue surface forms a smooth convex curve. There is no distinct bunching of the tongue front or concavity behind the front region. This suggests tip raising and a sublingual cavity.
- FRONT BUNCHED – the front of the tongue has a distinctly bunched configuration (the tip and blade remain lower than the rest of the tongue front). A dip in the tongue's surface behind the bunched section is also apparent.
- MID BUNCHED – the front, blade and tip are low, while the middle of the tongue is raised towards the hard palate.

These were then reduced to just tip or front up vs. bunched. We adopt this binary approach here, using as cover terms "R" (raised-or-retroflexed tip) and "B" (bunched). Dynamics suggest that in R types, the tongue tip forms the primary constriction for /r/, usually with a clearly apical orientation, while in B types, it is the tongue front (or even mid-dorsum) that forms the primary bunched constriction, with a clearly non-apical approximation of the articulators. More detailed description or quantitative analysis of R types (particularly from single target images) requires better information than ultrasound alone can provide, since R type articulations result in loss or distortion of the tip in the image due to the sublingual cavity. Artefacts due to the near parallel orientation of the ultrasonic echo-pulses to the superior tongue surface in retroflex also apply [28]. The bunched articulations, on the other hand, are typically clear and easily measurable in the image, having an anterior surface that dips down towards or even reaching the lower incisors or floor of mouth. In the "DF" system of Delattre and Freeman [6], B types correspond to types 2-4, and R to types 5-8.

In order to ensure consistency between the different datasets, the 1st author has applied these R/B categories to the onset /r/ data from these two datasets in consultation with 2nd author and to both onset and coda data from the ULTRAX datasets in consultation with the 3rd author.

Every token from every speaker was transcribed into these categories, then each speaker was given a single label for onset and one for coda (which might include syllabic rhotic nuclei). For example, though a following high vowel may make the appearance of R types less likely [17] on the whole, onset types tended to be the same, independent of the following vowel. If both onset and coda allophones were bunched, the system types was "BB". If the tip was raised in both, it was "RR." Mixed systems were "RB" or "BR" (i.e. B and R in onset-coda order).

Each speaker's allophonic system is therefore potentially subtle, i.e. *consistent* in the general shape of their /r/, either RR or BB, or categorical, i.e. having two strongly different allophonic types, either in RB or BR distribution. Six speakers from

ULTRAX were excluded due to non-rhotic Anglo English influence or mixed dialect, plus one speaker with a non-approximant /r/ (tap or trill) in WCB12.

We do not restrict /r/ by its vowel context (though most adjacent V are non-high). We examine /r/ that is a singleton, or is in a cluster, limited to *labial* clusters to avoid strong lingual coarticulation. Some "coda" /r/ may be syllabic nuclei [14], [17].

2.2. ECB08 and WCB12 datasets

Two repetitions of ten coda /r/ lexemes per speaker with a range of vowel qualities have been previously analysed from ECB08 [13]: *beer*, *bear*, *far*, *bar*, *par*, *purr*, *fur*, *for*, *bore*, *poor*. Two more lexemes were elicited from the middle-class speakers: *sure*, *pure*. There were, however, only two items with onset /r/, *rum* and *ram*, so while the coda data is highly reliable, onset evidence is weaker (but see [22] for a vowel analysis using only one token per speaker.)

WCB12 had a focus on mimicry, with coda /r/ in pseudo-words, not analysed here. Coda /r/ appeared in 27 real lexemes (N=2), analysed in [15]: *peer*, *ear*, *fear*, *beer*, *air*, *bear*, *hair*, *pair*, *fir*, *her*, *err*, *bar*, *far*, *par*, *for*, *or*, *fur*, *purr*, *her*, *fir*, *bore*, *more*, *oar*, *pore*, *boor*, *moor*, *poor*. Eight real words with onset /r/ fitting our criteria were collected (N=2): *room*, *rum*, *reef*, *proud*, *rope*, *road*, *ref*, *ram*.

2.3. ULTRAX datasets

ULTRAX investigated how real-time visual biofeedback from UTI might work in speech therapy intervention. Two groups of typically-developing children aged 6-12 (both planned as n=30) were recorded undertaking a variety of tasks [5]. The participants were recruited via university staff and students, and from local schools, without social stratification or strict accent selection, though the majority impressionistically had Scottish accents.

In addition to the core experiments and other assessments and tasks, Group 1 (usable speakers n=28) read the 50-word DEAP phonology assessment [7], the ten word DEAP diagnostic screen (two repetitions of each word) and some others. Ten lexemes contained coda /r/ after a range of vowels: *are*, *ear*, *oar*, *square*, *burp*, *parp*, *feather*, *tiger*, *helicopter* (N=3), *spider* (N=3). Seven lexemes had onset /r/: *rabbit*, *frog*, *bread*, *pram*, *bridge* (N=3), *umbrella* (N=3), *zebra*.

Group 2 had fewer materials, with more phonotactic limitations and confounds of presentation order. Of all the datasets, it provides the weakest evidence, because in addition to the core experiments on non-English sounds, just the ten-item DEAP screen was collected, plus an additional word, giving onset information (N=2) from: *bridge*, *umbrella*, *rap*. Coda /r/ was exemplified by two words (N=2): *helicopter*, *spider*.

For both groups, each word was produced without any carrier phrase, either as a single word or, more often, in a list of up to four words, from orthographic prompts or repetition of an adult model. The list productions were not randomised, so that word-to-word coarticulation effects might have occurred, providing a confound. The most important case is that the words *helicopter*, *bridge* occurred in sequence with the possibility of /r/-to-/r/ coarticulation (relevant for subject #39, see below).

3. SCOTTISH ENGLISH

Taking together BB and RR systems as examples of phonetically subtle, consistent allophonic systems, in the two sociophonetic studies they make up approximately two thirds of all systems. The eleven mixed systems were all RB: R in the onset and B in the coda (Figure 1).

Figure 1: Approximant allophony types from two socially-stratified Scottish-accent studies. N=30.

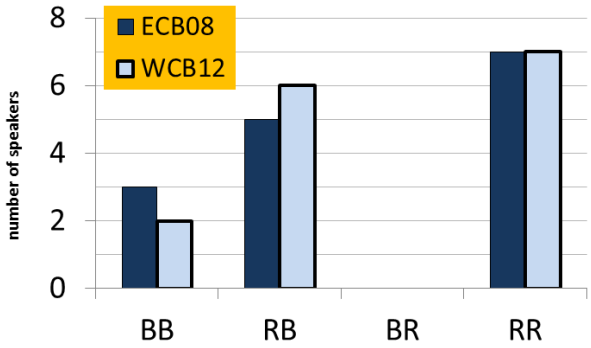
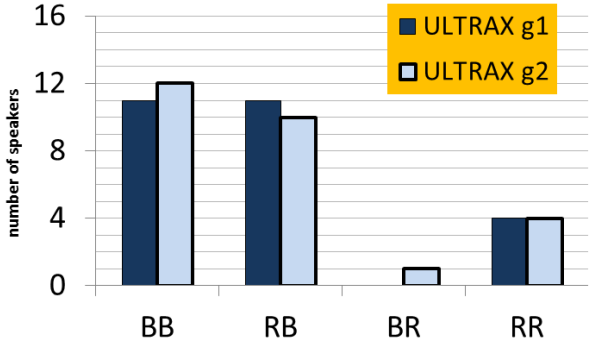


Figure 2: Lingual approximant allophony types from ULTRAX children. N=53.



Turning now to the ULTRAX studies, Figure 2 shows that the consistent systems (BB, RR) make up just over two thirds of the speakers. This time, the consistent speakers are predominantly BB: perhaps this reflects a more middle class pool of participants.

The 22 mixed systems included 21 from children who were clearly RB and one (#39TDM, Group 2) who was ambiguous. This speaker had some tip raising in pre-pausal *spider*, but coexisting with a basic B shape. His *helicopter* was bunched, but since it was immediately followed by *bridge*, this may have been due to coarticulation. Though ambiguous, we classified this unusual speaker as BR.

4. AMERICAN ENGLISH

It is useful to compare our results to the main study which has used ultrasound to describe contextual influences on the allophony of American English /r/ [17]. This rhotic variety has an approximant /r/, but its tongue shape or timing appears to lack social meaning. In [17], more subtle aspects of the phonotactic environment of /r/ than plain onset/coda were manipulated, and more subtle classification applied, using the DF types [6].

Unsurprisingly, therefore, speakers showed greater systematic variation, with only around half the 27 speakers in [17] being classified as invariant (their Table 1 has N=16). They were predominately B types (N=14, mainly DF type 4 N=10), with fewer R type (N=2, one each of DF type 7 and type 8).

The eleven categorically variable speakers were influenced by the segmental context of the /r/: "retroflex /r/ typically occurs in contexts without antagonistic tongue shapes: next to labials, word boundaries, and back vowels" ([17] §2.3.1). The range of environments leads them to propose a holistic analysis merging syllable and segmental aspects, in which "the bunched-retroflexed boundary is drawn in different places among a range of environments more or less favorable to each production strategy" ([17] §2.3.2).

Their approach does not, therefore, tease apart segmental from syllabic influence, and a context-free analysis of the syllabic role of /r/ was not included. The limited per-speaker materials available in the Scottish English datasets analysed above are fit for that purpose: we grouped singleton /r/ with labial+/r/ clusters as a relatively neutral context, and note that there is a minimal influence from /i/ or other de-retroflexing factors. This provides a simple onset vs. coda comparison.

Table 2: Approximant allophone types from [17], just neutral onset/coda syllabic contexts. N=27.

BB	RB	BR	RR
14	8	0	5

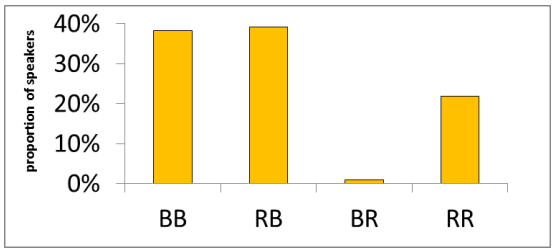
To address this question with the American data, we recalculate [17]'s systems and discard variation arising due to these finer grained, segmental, factors. On this basis, re-examination of their Table 1 reveals a pattern that fully confirms our findings (Table 2).

5. SUMMARY AND CONCLUSION

The segmental context of post-alveolar /r/ is known to influence its allophonic realisation [17]; and indeed the tongue shape of /r/ in turn influences *its* context (a) in synchronic variation (/s/ can sounds /ʃ/-like in /str/ [1], [17]) and (b) in phonology (see both [14] and standard English's /ʃr/ but */sr/).

Here, a novel allophonic pattern based on basic onset / coda syllable affiliation is revealed, based on five separate studies with different materials across two otherwise very distinct rhotic dialects of English (Figure 3). The asymmetry found requires a syllabic explanation, linking R types to onsets and B types to codas/nuclei, *for those speakers who vary*.

Figure 3: Overall rates of allophonic systems



Why are BR systems extremely rare? An *a priori* approach based on a strong onset / weak coda hypothesis, or general domain-initial strengthening (e.g. [12]) might suggest that a retroflexed shape (R) for /r/ is inherently more rhotic ("stronger") than a bunched one (B). If so, the R shape might be more compatible with "strong" onsets. But then, why is R rather than B is associated with weaker derhoticised codas in working-class Scottish English? Or, perhaps there is an intrinsic link between the R shape and the dynamic tendency for synchronised, in-phase gestural alignment in onsets as opposed to codas ([3], [4], [24], [9]), and that R is more compatible with in-phase timing than B is. But this is problematic too: temporal gestural dissociation in Scottish English codas tends to affect R types, while the gestures of B codas tend to be co-produced [17]. Scottish BB codas tend to both be more strongly rhotic *and* show less dissociative delay of the anterior gesture [16].

Ironically, consistent speakers (RR or BB) are more amenable to quantitative phonetic studies of subtle continua of timing and strength than speakers with categorically discreet allophones. But theories need to account for both types of allophony, and for the emergence of categories in the first place.

ACKNOWLEGMENTS

For financial support we thank EPSRC (ULTRAX EP/I027696/1) and ESRC (RES-000-22-3032 & RES-000-22-2032). Thanks to Alan A. Wrench, Steve Cowen, students at QMU, and our participants and their families.

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